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Review

Intermittent photic stimulation as an activation method for electroencephalographic screening of aircrew applicants

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Abstract

Disqualifying criteria for aircrew in Europe (JAR-FCL 3) are, besides a diagnosis of epilepsy after the age of 5 and a history of episode(s) of disturbance of consciousness, epileptiform paroxysmal electroencephalographic abnormalities and focal slow waves. Intermittent photic stimulation (IPS) provokes in about 0.5% of healthy subjects (range 0–2%) a photoparoxysmal response and is most often the only abnormality (70–90%). The literature is scarce and shows great diversity in methodology. Standardized IPS with simultaneous video will not only allow collection of sufficient data for proper epidemiological studies, but can also reveal clinical and often unnoticed or misinterpreted signs and symptoms like myoclonia, loss of consciousness, and occipital seizures with visual auras. The pilot (sleep deprivation, strong sunlight) and the traffic controller (stress, monitors) are more prone to visually induced seizures. Furthermore, the increasing exposure to potentially seizure-triggering visual stimuli might have its impact in a more indirect or cumulative way.

Keywords: Photoparoxysmal response; Aircrew; Photosensitivity; Helicopter; Intermittent photic stimulation; Air traffic controller

1. Background

1.1. Rationale in aircrew selection

Intermittent photic stimulation (IPS), like hyperventilation, is used to evaluate the seizure threshold of an individual and has been performed as part of the routine electroencephalogram (EEG) since the 1950s using stroboscopic flicker [1]. With IPS, the EEG may show an abnormal reaction, a so called photoparoxysmal response (PPR), defined as regular or irregular polyspike or spike and wave activity, starting or maximum over the posterior areas with or without generalization. Important studies by Walter and Walter, and later by groups led by Gastaut in France and by Bickford in the United States, yielded basic information about those EEG responses to IPS which were reliably linked to seizures [2].

Sunlight, reflected from the sea, snow, etc., and black and white striped patterns alone or in combination are strong provocative environmental stimuli. TV screens and monitors are other potentially provocative stimuli, especially in those with a combination of sensitivity to IPS and to striped patterns [3]. In aviation, pilots are confronted with strong sunlight and artificial lights; rotating helicopter blades are notorious for evoking generalized tonic–clonic seizures [4]. EEG recording with IPS and pattern stimulation can help in predicting vulnerability to visually evoked seizures. Visual sensitivity is, like juvenile myoclonic epilepsy, strongly enhanced by sleep deprivation and stress and, when asymptomatic in normal daily life, can become symptomatic under these conditions. In addition, IPS and pattern stimulation allow us to determine whether visual stimuli can elicit clinical phenomena such as eyelid myoclonia, more massive myoclonic jerks, absence seizures, an occipital

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seizure, or even an unwanted and actually unnecessary generalized convulsion in the laboratory.

1.2. Epidemiology

1.2.1. PPR in epilepsy patients

Many studies address the issue of visual sensitivity and PPR in epilepsy patients. The age at onset of the PPR is between 8 and 25 years, with the maximum around puberty; there is a clear female preponderance (60%) and a decline in sensitivity to IPS after age 30 in about 30 to 60% of subjects [5,6]. TV, videogames, discotheque lights, and sunshine flickering through trees or on snow are among the most provocative environmental stimuli. Variations exist in the degree of sensitivity, including the range of provocative flash frequencies (photosensitivity range); the threshold for light intensity; the duration of stimulation; whether the eyes are open, closed, or closing; and whether a subject is sensitive to striped patterns and to what extent. About 5% of all epilepsy patients have a clear history of generalized tonic–clonic seizures (GTCSs), absences, myoclonic jerks, or focal seizures evoked by visual stimuli in daily life and show a PPR in the EEG; 40% of those photosensitive patients have exclusively visually induced seizures, while others have a combination of spontaneous and visually induced seizures [7]. Video/EEG monitoring shows that 75 to 100% of IPS-sensitive persons have at least subtle clinical signs with IPS [8]. Half of these, however, do not notice brief but clear-cut seizures accompanying the PPRs, such as eyelid myoclonia, jerks, and brief alteration of consciousness [9].

In a community survey of adolescents with epilepsy in Wales, Clement and Wallace found that approximately 10% were photosensitive [10]. It is not well known how many will lose their sensitivity after age 30; study results give ranges of 25–60% for persistence of the PPR [11,12]. Large-scale studies in first-degree relatives of visually sensitive children have shown PPRs in up to 40% of siblings and 10% of parents [13]. The PPR is now believed to be a genetic trait that can be expressed in different ways, influenced by age, sex, concomitant cerebral states, and provocative visual stimuli [14].

1.2.2. Normal populations

Studies of photosensitivity in normal populations have been performed mostly in children and adolescents and in aircrew candidates.

1.2.2.1. Adolescents and adults. A prospective nationwide study to determine the incidence of clinical photosensitive epilepsy was done in the United Kingdom: 191 new cases were found who had had at least one epileptic seizure and whose first EEG showed a PPR on IPS [15]. The annual incidence of cases of epilepsy with a PPR on their first EEG was conservatively estimated to be 1.1/100,000, representing approximately 2% of all new cases of epilepsy. When restricted to patients 7–19 years old, the annual incidence rose to 5.7/100,000. This represents approximately 10% of all new cases of epilepsy presenting in this age range and is consistent with other reports. It confirms that photosensitivity is an important feature in relation to epilepsy, especially in childhood and adolescence.

So et al. selected all photosensitive subjects (age range, 3–44 years) who had not had a clinical seizure out of 28,215 EEGs from the Marshfield hospital (Rochester, MN, USA) from 1976 to 1982 [16]. Most subjects (75%) with a PPR had had a seizure; EEGs in the study group had been performed for other indications such as headache, dizziness, and brain tumor, and 188 such subjects were identified. IPS was performed with a Grass PS 22 at 20-cm distance at frequencies of 3–41 Hz for 10 seconds each with eyes closed. Of the 188 subjects without seizures, 33 (18%) could be followed up for 6–12 years (average, 9 years), and none of these developed seizures. Similar results were found in another American study in 3557 patients and 48 normal subjects [17]. None of the 48 normal subjects showed a generalized PPR. PPRs were seen in 35 (1%) patients, of whom 27 (77%) had a definite history of epilepsy, 3 (9%) had a questionable history, and 5 (14%) had had no seizures.

Another American study reported EEG investigations after nocturnal sleep deprivation in 100 active-duty soldiers aged 18–45 years acting as volunteers for large neurological studies. The EEGs showed no abnormality at rest or with IPS with a Grass PS 22 [18]. This rather small group was very highly selected with exclusion of epilepsy and any neurological, neuropsychological, or MRI abnormality.

1.2.2.2. Aircrew candidates

Military aviation. One of the first reports suggesting that visual stimuli play a role in unconsciousness in military pilots was made in 1956 by Powell [19]; flickering sunlight reflected off the propellers was considered to be of importance. A study in 210 Dutch air force trainees and 90 healthy young men in 1955 showed a PPR in 3 (1%) with, respectively, absence seizures, postvaccination encephalitis, and a cerebral contusion [20]. The only report to correlate EEG abnormalities at initial medical screening with later crashes dates from the 1950s in Denmark; 682 air force jet pilots were studied. A higher crash rate due to pilot error was noted in those with EEG abnormalities, including epileptiform activity during rest and after hyperventilation or only during 3 minutes of IPS [19]. No details were given, however, on how many of the abnormal EEGs included PPRs.

A 10-year experience from 1965 to 1975 of the US Air Force in male aviators 18–55 years old revealed that 166 of the 7760 screening EEG recordings (2%) showed epi-